

UNCLASSIFIED

AD 273 548

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

273548



Quarterly Progress Report

Q-B1856-2

**DEVELOPMENT OF A UNIVERSAL RADIO
FREQUENCY PROTECTED SQUIB**

by

Paul F. Mohrbach
Melvin R. Smith

October 1, 1961 to December 31, 1961

Prepared for

U.S. NAVAL WEAPONS LABORATORY
Dahlgren, Virginia
Code WHR

Contract No. N178-7902

RELEASED TO ASTIA
WITHOUT RESTRICTION
OR LIMITATION

THE FRANKLIN INSTITUTE
LABORATORIES FOR RESEARCH AND DEVELOPMENT
PHILADELPHIA PENNSYLVANIA

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*
Quarterly Progress Report

G-B1856-2

DEVELOPMENT OF A UNIVERSAL RADIO
FREQUENCY PROTECTED SQUIB

by

Paul F. Mohrbach
Melvin R. Smith

October 1, 1961 to December 31, 1961

Prepared for

U.S. Naval Weapons Laboratory
Dahlgren, Virginia
Code WHR

Contract No. N178-7902

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

ABSTRACT

Experiments were conducted to determine if it is possible to attenuate RF energy in a transmission line by coupling the line to a transformer with a lossy core. This device was designed specifically to provide high core loss and eddy current loss. Tests over the frequency range from 20 kc to 1 Mc indicated that adequate RF protection could be provided for an EED having a 1-ohm bridge wire. It was possible to fire MARK 1 Mod O squibs through the transformers with a 2 millisecond pulse of 14 volts magnitude.

Dissipative filters of various types were tested and showed promise. An analog computer is being used to evaluate these filters and gain information as to arrangements which would give as much RF attenuation as possible without unduly reducing the firing sensitivity of an EED.

The evaluation of solid state devices was continued, but only transistor switching circuits showed promise; however, these required more complex firing circuits than those now ordinarily used.

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT.	i
1. INTRODUCTION.	1
2. EXPERIMENTAL PROGRAM.	1
2.1 Lossy Core Devices	1
2.1.1 Biased Core Device.	1
2.1.2 Toroidal Core Device.	3
2.1.3 Isolating Transformer	4
2.2 RF Filter Devices.	6
2.2.1 Reactive Filters.	6
2.2.2 Dissipative Filter.	7
2.3 Solid State Protective Devices	10
2.3.1 Transistor Switching Devices.	10
2.3.2 Light-Dependent Resistor Devices.	11
2.3.3 Diode Protective Devices.	12
2.3.4 Other Solid State Devices	13
3. CONCLUSIONS AND FUTURE PLANS.	14
4. ACKNOWLEDGEMENTS.	15

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
2-1	Biased Core Protective Device.	2
2-2	Toroid Protective Device	2
2-3	Solenoid Coil Protective Device.	6
2-4	Simple Inductance Filter	7
2-5	Dissipative Filter Network	7
2-6	Modified Dissipative Filter.	8
2-7	Light-Dependent Resistor Circuit	12
2-8	Diode Protective Circuit	13
2-9	Zener Diode Protective Circuit	14

LIST OF TABLES

<u>Table</u>		<u>Page</u>
2-1	Test Results - Biased Core Protective Device . . .	3
2-2	Test Results - Toroid Protective Device.	4
2-3	Voltage Ratio Tests - Solenoid Coil #1	5
2-4	Power Division in Filter Circuit - Figure 5. . . .	9
2-5	Power Division in Modified Filter Circuit - Figure 5	9
2-6	Power Division - Multi-Element Dissipative Filter	10
2-7	Transistor Protection Test - Collector Voltage Applied.	11

1. INTRODUCTION

The purpose of this program is to develop an electroexplosive device (EED) which will be protected against accidental initiation by radio frequency energy. In the past, all attempts to provide protection have been applied to EED's which are already in being. Thus, the efforts to provide the maximum protection were handicapped by restrictions on changing the external configuration or the normal firing or performance characteristics of the original EED. In this project, the latest state-of-the-art techniques will be applied with the objective of minimizing the RF hazard; size and firing characteristics of the EED are of secondary consideration.

2. EXPERIMENTAL PROGRAM

2.1 Lossy Core Devices

One of the usual problems facing the engineer when designing a transformer is that of keeping core losses to a minimum. This problem becomes more difficult as frequency increases. We think it possible to attenuate RF energy in a transmission line by coupling two portions of the line to a transformer having large losses. It is known that eddy current losses in a transformer core of fixed design vary directly as the square of the frequency. This loss ratio makes such a device attractive for our purpose. Several of these transformer type devices were designed and tested during this report period.

2.1.1 Biased Core Device

A transformer device similar to that shown in Figure 2-1 was constructed to determine how RF losses might be affected by operating the core at various points on the B-H curve and to ascertain the effects of varying the gap width and gap materials in the core. All three coils were wound with 200 turns of #35 copper magnet wire. Tests were made in which the input coil was driven at various frequencies from an oscillator with a signal of 40 volts peak to peak. Test results are recorded in Table 2-1.

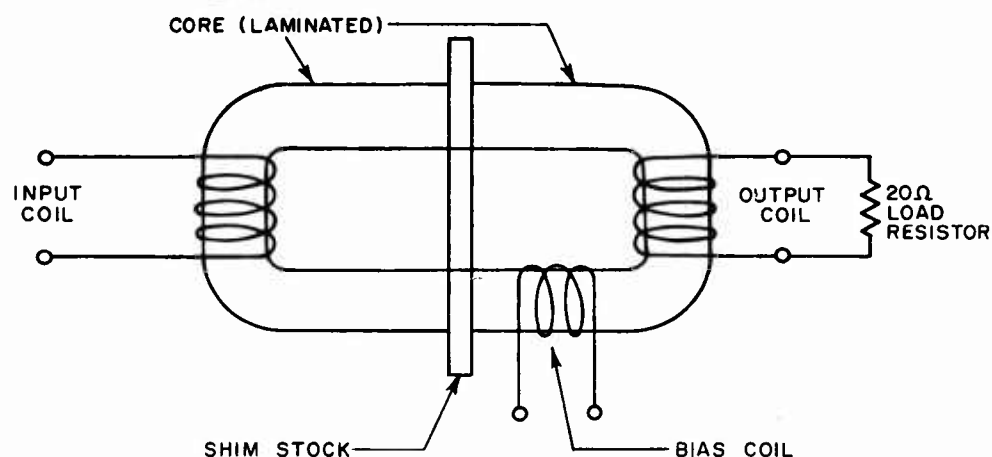


FIG. 2-1. BIASED CORE PROTECTIVE DEVICE

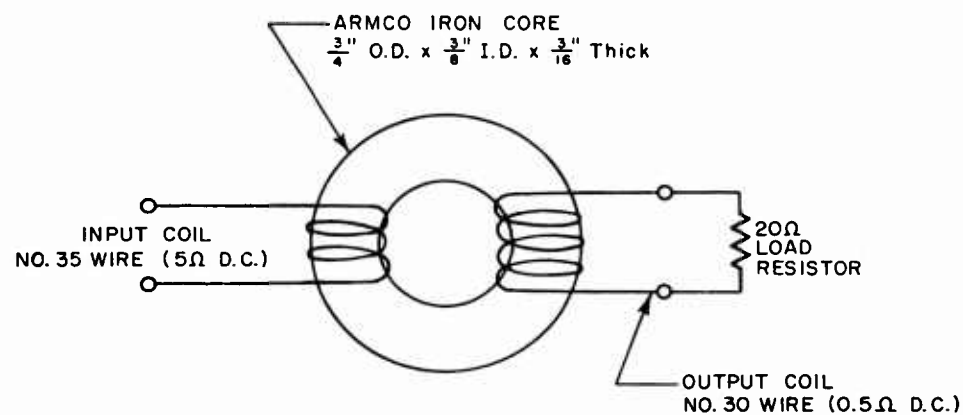


FIG. 2-2. TOROID PROTECTIVE DEVICE

THE FRANKLIN INSTITUTE • Laboratories for Research and Development

Q-B1856-2

Table 2-1

TEST RESULTS - BIASED CORE PROTECTIVE DEVICE

<u>Frequency</u>	<u>Input (Volts P-P)</u>	<u>Output (Volts, Peak-to-Peak)</u>			
		<u>Polepieces Clamped; No Shim</u>		<u>With 0.031" Brass Shim</u>	
		<u>No Bias</u>	<u>12 V DC Bias</u>	<u>No Bias</u>	<u>12V DC Bias</u>
5 KC	40	1.00	.38	.15	.10
20 KC	40	.60	.25	.07	.05
50 KC	40	.25	.10	.005	.005

This device was also tested for transfer of capacitor discharge pulses by discharging a 5 μ f capacitor, charged to 25 volts, into the input coil. The magnitude of the output pulse measured 1.2 volts without the brass shim and 1.0 volt with the shim in place.

These tests indicated that the losses in a transformer type device could be expected to increase with frequency; that the losses can apparently be varied by changing the operating point on the B-H curve; that discontinuities in the flux path would increase the isolation of the circuit for RF without having too serious an effect on the DC transfer characteristics.

2.1.2 Toroidal Core Device

We conducted experiments with a device similar in its general form to the conventional pulse transformer. This device was constructed as shown in Figure 2-2. The core was machined from a bar of soft Armco iron; then wound with coils of varying numbers of turns of magnet wire. The results of attenuation tests of this device are shown in Table 2-2.

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

Table 2-2

TEST RESULTS - TOROID PROTECTIVE DEVICE

<u>Frequency</u>	<u>Input (Volts P-P)</u>	<u>Output (Volts P-P)</u>
5 KC	40	.08
20 KC	40	.40
50 KC	40	2.00

When the device was tested for pulse transmission, results were unsatisfactory as far as energy transfer was concerned. The output pulse had the appearance of a voltage spike of short duration which appeared to be independent of the input pulse width. This pulse behavior, together with the fact that capacitive coupling seemed to be increasing as the frequency increased, led to the suspension of experiments with this device.

2.1.3 Isolating Transformer

Several test units were constructed having separate input and output windings on a cylindrical core of soft Armco iron. By experiment, it was found that the pulse transfer characteristics were reasonable, but again there was apparently RF coupling at the higher frequencies probably due either to radiation or to capacitance effect.

Previous work had shown that material having high permeability and low resistance, and which had been cold worked, should have maximum eddy current loss, the desired condition for this application. In order to get the greatest attenuation in a choke having such a core, we must aim for the greatest inductance. In proposing the use of two windings, with a common lossy core, to serve as an isolating transformer, we make the comment that the design of such is somewhat cut-and-try. To reduce the dc resistance of such a coil, and yet obtain a maximum inductance, we decided to use a coil with a length less than the diameter. This configuration should give maximum inductance for a given length of wire,

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

and therefore maximum eddy current loss. The outer diameter was limited to 2 inch maximum, which would fit within an easily obtainable metallic tube. The depth of windings was fixed by the turns ratio required by voltage requirements. The inside diameter was 1/2 inch, so that a section of soft Armco iron presently available might be used for the core.

In order to eliminate high frequency coupling, shielding was tried between the coils as shown in Figure 2-3. Tests were made using an oscillator and a power amplifier to drive the input coil while the resulting signal on the output coil was measured across a 1 ohm load. The results of these tests, shown in Table 2-3 indicate that significant protection from RF energy is provided. Isolating transformer number one was made with a 1:2 step-up turns ratio. In testing, the device was supplied with a firing pulse by The Franklin Institute Laboratories Universal Pulser, (FILUP), and MARK 1 MOD 0 squibs were connected to the output coil. Five of six squibs were fired by a 2 millisecond constant current pulse of 14 volts magnitude. The sixth squib fired on the application of a 20 volt pulse of the same type.

Table 2-3

VOLTAGE RATIO TESTS Solenoid Coil #1			
Frequency	Voltage In (V_1)	Voltage Out (V_2)	<u>Protection Constant</u> $20 \log_{10} \frac{V_1}{V_2}$
1 KC	5	.2	27.9
1.5	5	.2	27.9
2.0	4.8	.2	27.8
5	6.8	.2	30.8
10	11.0	.2	34.8
20	28.0	.2	42.0
30	64	.2	50.2
40	56	.1	55.0
50	32	.1	50.2
70	24	.1	47.6
100	22	.1	46.9
200	52	.1	54.4
500	26	.1	48.3
800	11	.05	46.9
1 Mc	11	.05	46.9

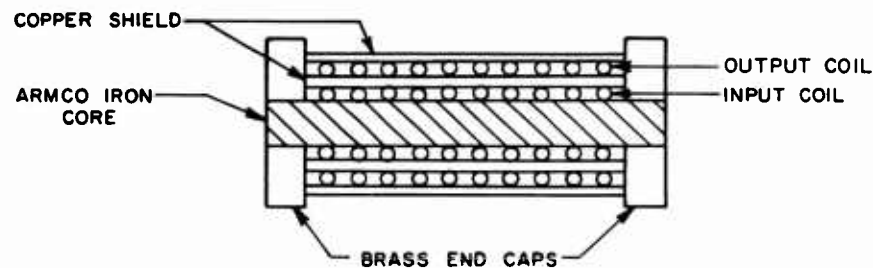


FIG. 2-3. SOLENOID COIL PROTECTIVE DEVICE CROSS SECTION

2.2 RF FILTER DEVICES

RF filters are devices which combine elements to bypass or dissipate RF energy, before it can reach the initiating element of the EED. The evaluations of devices developed in this study are believed to be valid only with the specified terminating impedance, since this quantity has a tremendous effect upon filter performance.

2.2.1 Reactive Filters

The most simple filter evaluated during this report period consisted of a coil and a resistor in parallel, inserted in the firing line as shown in Figure 2-4. An attempt was made to measure the attenuation in a matched system. At 10 Mc a loss of 21 db was measured, but complete impedance matching was not possible; therefore, this value should be considered only as insertion loss. Insertion loss was measured for this same device in the system shown in Figure 2-2 of Report Q-B1856-1; the same loss was measured.

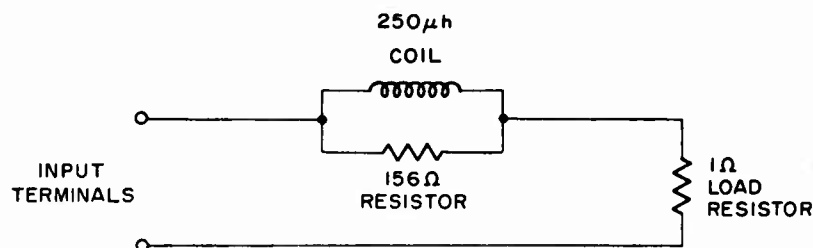


FIG. 2-4. SIMPLE INDUCTANCE FILTER

2.2.2 Dissipative Filter

A filter using more elements to make a power divider was constructed according to Figure 2-5. When evaluated in the 10 Mc system, an insertion loss of 30 db was measured. Additional tests were made to

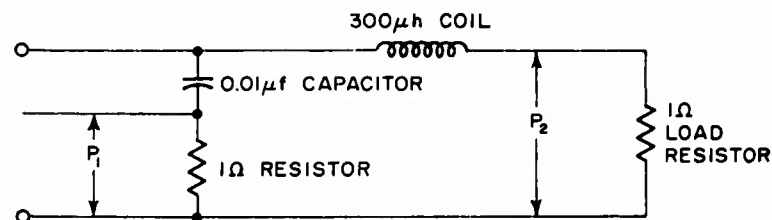


FIG. 2-5. DISSIPATIVE FILTER NETWORK

determine the power dissipated in the different elements of the circuit. Power was measured at the points labeled P_1 and P_2 in Figure 2-5 and was distributed as shown in Table 2-4. This circuit did not provide adequate RF protection. The value of the capacitor in the circuit in Figure 2-5 was changed to 5 μ f. This made a marked change in the ratio

THE FRANKLIN INSTITUTE • Laboratories for Research and Development

Q-B1856-2

Table 2-4

POWER DIVISION IN FILTER CIRCUIT - FIGURE 5

<u>Frequency</u>	$\frac{P_1}{P_1 + P_2}$	$\frac{P_2}{P_1 + P_2}$	$\frac{P_1}{P_2}$
10 KC	.002	.998	.002
20 KC	.005	.995	.005
50 KC	.148	.852	.174
100 KC	.692	.308	2.25
200 KC	.918	.082	11.2
300 KC	.978	.022	44.3
500 KC	.9911	.0099	100
1 Mc	>.992	<.008	

Note: Capacitor = .01 mfd.

Table 2-5

POWER DIVISION IN MODIFIED FILTER CIRCUIT - FIGURE 5

<u>Frequency</u>	$\frac{P_1}{P_2}$
10 KC	36
20 KC	49
30 KC	100
50 KC	400
100 KC	400

Note: Capacitor = 5 μ f

Q-B1856-2

of the power dissipated in the load resistor to that dissipated in the protective resistor. Results of this test were as shown in Table 2-5. The level of attenuation was somewhat higher than the previous test but still marginal.

The dissipative filter was modified by adding more filter elements, with values as shown in Figure 2-6. Response of this filter was checked at high frequencies with results as shown in Table 2-6.

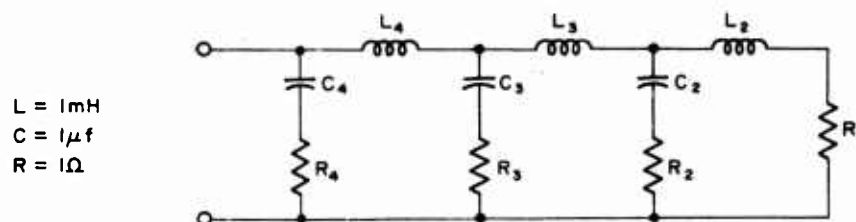


FIG. 2-6. MODIFIED DISSIPATIVE FILTER

$$\text{Power Ratio} = \frac{P_{\text{in}}}{P_{\text{out}}} = \frac{P_{R_1} + P_{R_2} + P_{R_3} + P_{R_4}}{P_{R_1}}$$

The results of the tests of this type of filter showed promise; a program has been set up on an analog computer to determine the effects on attenuation when the values and ratios of the circuit components are changed, and to determine how such a filter might distort different types of firing pulses.

Table 2-6

POWER DIVISION - MULTI-ELEMENT DISSIPATIVE FILTER

<u>Frequency</u>	<u>5 mc</u>	<u>7 mc</u>	<u>10 mc</u>	<u>15 mc</u>	<u>20 mc</u>	<u>30 mc</u>	<u>50 mc</u>
Element							
E_{R_1}	.01	.03	.03	.02	.02	.01	.005
E_{R_2}	.02	.04	.04	.02	.02	.01	.005
E_{R_3}	.03	.06	.05	.02	.02	.01	.005
E_{R_4}	1.6	2.8	1.2	.60	.80	.60	.005
Power Ratio	2.56×10^4	8700	16000	13612	6412	3603	4

2.3 SOLID STATE PROTECTIVE DEVICES

Studies of solid state devices which may be used to provide RF protection for EED's were continued during this report period. Several types of devices were studied including transistor switches, light-dependent resistors, and diode networks.

2.3.1 Transistor Switching Devices

Evaluation of the transistor circuit shown in Figure 2-5 of the previous report (Q-B1856-1) was continued. During this report period, insertion loss measurements were made with the device operating with collector voltage applied. When the 2N1162A transistor was tested with 12 volts on the collector and with the RF signal applied to the base, the results were as shown in Table 2-7. In the table the term "protection constant" is used instead of "db attenuation" because the input and output impedance were not of the same value. This device appears to provide some protection from 20 KC to 3 Mc.

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

Table 2-7

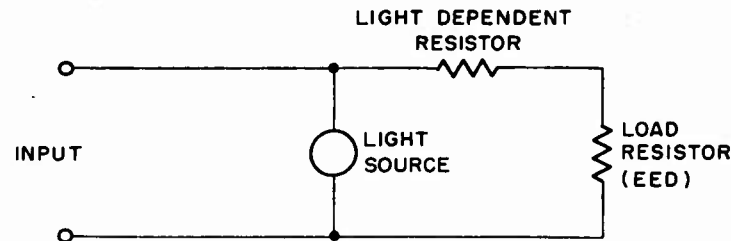
TRANSISTOR PROTECTION TEST - COLLECTOR VOLTAGE APPLIED

<u>Frequency</u>	<u>Voltage In</u>	<u>Voltage Out</u>	<u>Protection Constant*</u>
1 KC	11.0	.12	20.96
2 KC	11.0	.12	20.96
5 KC	11.0	.08	40.13
10 KC	11.0	.07	40.19
15 KC	11.0	.06	40.26
20 KC	11.0	.05	40.34
30 KC	11.0	.04	40.43
40 KC	11.0	.035	40.49
50 KC	11.0	.03	40.56
100 KC	12.0	.03	40.60
150 KC	12.0	.025	40.68
200 KC	12.0	.025	40.68
500 KC	12.0	.03	40.56
1 Mc	10.0	.07	40.15
2 Mc	10.0	.20	20.69
3 Mc	9.0	.22	20.61
5 Mc	7.0	5.6	1.92
7 Mc	5.0	4.8	.34
9.8 Mc	4.0	3.4	1.36

$$* \text{ Protection Constant} = 20 \log_{10} \frac{\text{Voltage In}}{\text{Voltage Out}} .$$

2.3.2 Light-Dependent Resistor Devices

Light-dependent resistors (LDR) might be used in a circuit similar to that shown in Figure 2-7 to provide RF protection for electroexplosive devices. Upon receipt of a firing signal, the light source is activated by the dc voltage of the firing pulse, causing the resistance of the LDR to drop from megohms to tens of ohms, permitting the pulse to pass through to the load. On the other hand, when RF voltages are applied to gas tubes or electroluminescent panels, we have a different result; as frequency is increased, the light output decreases. This circuit, therefore, would maintain its impedance to RF energy at a high level.

FIG. 2-7. LIGHT DEPENDENT RESISTOR CIRCUIT

Device A contained both light source and LDR in an integral sealed unit. These units were thought to have gas tube light sources, but when preliminary tests were made the light source was found to be an incandescent lamp. Therefore there was no apparent RF protection.

Device B comprised a separate LDR, mounted in a paper tube together with an NE-48 neon lamp as a light source. In this instance, it was possible to reduce the series resistance of the LDR from 1 megohm to 200 ohms, but 125 volts dc is required to produce this change. Further work on Device B has been suspended because other devices have been more promising.

2.3.3 Diode Protective Device

A superficial study was made of a circuit shown in Figure 2-8 which used 1N34A diodes as protective devices. When RF energy is applied at the input terminals of this circuit the current passes freely through both diodes during one half of the cycle providing a low impedance shunt for the EED. During the other half cycle, a large voltage drop occurs across D_2 , thus limiting the applied voltage across the EED. A measure of protection is thus provided. Tests at 100 kc and 1 Mc indicate that ratios $\frac{V_i}{V_o}$ of 100 are possible. When the firing pulse is applied to the input terminals, D_1 will burn out causing the firing current to pass through the EED bridge. Work was suspended on

this device because of the limited knowledge of diode burnout characteristics, and because EED bridge resistances of approximately 5000 ohms were indicated.

2.3.4 Other Solid State Devices

Other devices considered for protective systems are varistors and zener diodes. Varistors have a resistance which varies as the impressed voltage varies. They may be obtained with different response curves; i.e., resistance versus voltage. By using one or more varistors in a circuit, a unique voltage discriminating network may be developed. Two units whose characteristic curves intersect (for a specific voltage their resistances are equal) may be included in a bridge type network which would respond in an unique way for a specified voltage. The relatively high resistance of available varistors makes their use difficult in circuits for protective systems. Perhaps the effect of the high resistance might be lowered by use of modified circuitry. Varistors as a protective systems component have not been investigated further, since an obvious use of their characteristics is not presently evident.

We have considered the use of zener diodes in a network that would respond to a specified pulse height. Zener diodes have the property of passing virtually no current until the applied voltage, exceeds a certain characteristic value; at higher voltages, zener diodes appear as a low impedance. When two such diodes of differing characteristics are placed in a proper network a voltage gate is formed, requiring a specified voltage pulse to pass through the device. Such a network might be as shown in Figure 2-9. The voltage pulse required to transmit sufficient energy to the device may be restricted to be $V_1 < V < V_2$.

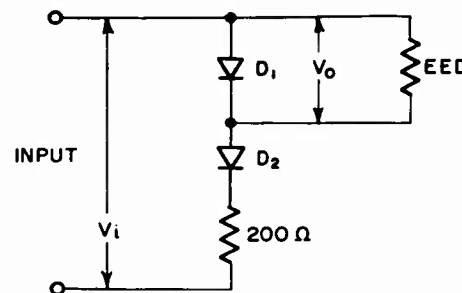


FIG. 2-8. DIODE PROTECTIVE CIRCUIT

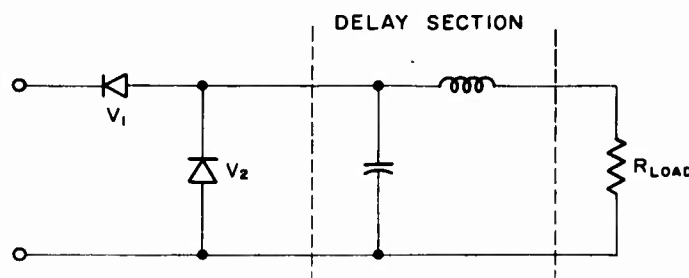


FIG. 2-9. ZENER DIODE PROTECTIVE CIRCUIT

The circuit to the right of the second diode may be used to delay the effect of the pulse upon the load thereby permitting V_2 to break down soon after V passes V_1 , if V exceeds both V_1 and V_2 .

Such a circuit concept is highly conjectural, and unconsidered factors as capacitive coupling may negate its usefulness at certain frequencies. This concept has not been studied further; more consideration is warranted before more intensive work is directed to study the concept. Even if such a network were feasible, it would place certain added restrictions upon the applicable firing stimuli. It is worth observing that safety always involves restrictions, and the degree of safety depends on the narrowness of the restrictions.

3. CONCLUSIONS AND FUTURE PLANS

In addition to the reactive filter described in the last report (Q-B1856-1) we now have the isolating transformer to provide protection from the lower frequencies in the RF spectrum (20 Mc to 1 Mc). We believe that such a device will provide protection even at high frequencies, but at the present time reliable measurement techniques in the frequency range above 1 Mc are not set up in the laboratory. These measurement techniques are being developed on other

THE FRANKLIN INSTITUTE • Laboratories for Research and Development

Q-B1856-2

programs and will be used on this program when their reliability is proven. The isolating transformer has an advantage over other protective devices in that the power level required to fire the EED needs to be only slightly increased. Consider the MARK 1 MOD 0 squib with which the solenoid device was tested. This EED should require approximately 1 volt DC across its one ohm bridge to fire. When fired through the transformer 14 volts DC are required across the 8-ohm input coil. The current required to fire has been increased by a factor of 1.75. This voltage and current are readily available from any usual vehicular power supply.

The modified dissipative filter shown in Figure 2-6 shows promise as an effective protective device. This circuit is being analyzed on the analog computer so that its characteristics may be made optimum. If the results of this computer study are favorable, this type of circuit might also be incorporated into a protected squib.

During the next report period the prototype RF-protected squib design will be completed and the prototype units constructed and tested.

4. ACKNOWLEDGEMENT

Portions of this report have been prepared by Ernst Schneck. Experimental work and measurements were conducted by Ramie H. Thompson and James S. Louie.

Paul F. Mohrbach

Paul F. Mohrbach
Project Leader

Melvin R. Smith

Melvin R. Smith
Project Engineer

Approved by

E. E. Hannum

E. E. Hannum, Manager
Applied Physics Laboratory

F. L. Jackson

Francis L. Jackson,
Director of Laboratories

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

DISTRIBUTION LIST

Commander
U.S. Naval Weapons Laboratory
Dahlgren, Virginia
Attn: Code WHR (3)

Contracting Officer
U.S. Naval Weapons Laboratory
Dahlgren, Virginia
Attn: Code SSCP

Office of Naval Research
University of Penna.
Rm. 213, Hare Building
Philadelphia 4, Pa.
Attn: Mr. R.L. Keane

Chief, Bureau of Naval Weapons
Department of the Navy
Washington 25, D.C.

Code: C-132
RAAV-3421
RM-15
RMMO-224
RMMO-235
RMMO-32
RMMO-33
RMMO-4
RMMO-43
RMMO-44
RMMP-343
RREN-32
DLI-31 (4)

Chief, Bureau of Yards and Docks
Department of the Navy
Washington 25, D.C.
Attn: Code D-200

Commander
U.S. Naval Ordnance Laboratory
White Oak, Maryland
Code ED
NO
Technical Library

Commanding Officer
U.S. Naval Ordnance Laboratory
Corona, California
Code: 561

Commander
U.S. Naval Ordnance Test Station
China Lake, California
Code: 556
4572

Commanding Officer
U.S. Naval Air Dev. Center
Johnsville, Pennsylvania
Code: EL-94

Officer-in-Charge
U.S. Naval Explosive Ordnance
Disposal Technical Center
U.S. Naval Propellant Plant
Indian Head, Maryland

Director
U.S. Naval Research Laboratory
Washington 25, D.C.
Code: 5410 (2)

Commandant of the Marine Corps
Washington 25, D.C.
Code: AO4C

Commander
Pacific Missile Range
P.O. Box 8
Point Mugu, California
Attn: Code 3260

Commanding Officer and Director
U.S. Navy Electronics Laboratory
San Diego 52, California
Attn: Library

Commanding Officer
U.S. Naval Ammunition Depot
Crane, Indiana
Code: 34

Commanding Officer
U.S. Naval Ordnance Plant
Macon, Georgia
Attn: Code PD 270

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

DISTRIBUTION LIST (Cont.)

Commander Naval Air Force U.S. Atlantic Fleet (CNAL 724B) U.S. Naval Air Station Norfolk 11, Virginia	Department of the Army Office Chief of Ordnance Washington 25, D.C. Attn: ORDGU-SA ORDTN ORDTB (Res. & Special Projects)
Commander Training Command U.S. Pacific Fleet c/o U.S. Fleet Anti-Submarine Warfare School San Diego 47, California	Office Chief Signal Officer Research and Development Division Washington 25, D.C. Attn: SIGRD-8
Commanding General Headquarters, Fleet Marine Force, Pacific c/o Fleet Post Office San Francisco, California Attn: Force Communications Electronic Officer	Commanding Officer Diamond Ordnance Fuze Laboratories Washington 25, D.C. Attn: Mr. Wm. Binkley - Code 420
Commander in Chief U.S. Pacific Fleet (Code 4) c/o Fleet Post Office San Francisco, California	U.S. Army Nuclear Weapon Coordination Group Fort Belvoir, Virginia
Commander Seventh Fleet c/o Fleet Post Office San Francisco, California	Director U.S. Army Engineer Res. & Dev. Labs. Fort Belvoir, Virginia Attn: Chief, Basic Research Group
Commander New York Naval Shipyard Weapons Division, Code 290 Naval Base Brooklyn 1, New York	Commanding Officer Picatinny Arsenal Dover, New Jersey Attn: Artillery Ammunition & Rocket Development Laboratory Mr. S.M. Adelman Attn: Mr. Abraham Grinoch, Chief Evaluation Unit Instrumentation Section, Bldg. 352
Commander Pearl Harbor Naval Shipyard Navy No. 128, Fleet Post Office San Francisco, California Code: 280	Commanding General Headquarters 2D4AADCOM Oklahoma City, AFS Oklahoma City, Oklahoma
Commander Portsmouth Naval Shipyard Portsmouth, New Hampshire	Commanding Officer U.S. Army Signal Res. & Dev. Lab. Fort Monmouth, New Jersey Attn: SIGEM/EL-GF

THE FRANKLIN INSTITUTE • Laboratories for Research and Development

Q-B1856-2

DISTRIBUTION LIST (Cont.)

Commander
U.S. Army Ordnance
Frankford Arsenal
Philadelphia 37, Penna.

Commander
U.S. Army Rocket and Guided
Missile Agency
Redstone Arsenal, Alabama
Attn: ORDXR-R (Plans)

Commander
Army Ballistic Missile Agency
Redstone Arsenal, Alabama
ORDAB-DSDG through ORDAB-HT
Attn: Mr. R.N. Eilerman

Commanding Officer
Office of Ordnance Res., U.S. Army
Box CM, Duke Station
Durham, North Carolina
Attn: Internal Res. Div.

Commanding General
White Sands Missile Range
New Mexico
Attn: ORDBS-G3

Commanding Officer
White Sands Missile Range, New Mexico
U.S.A. SMSA
Attn: SIGWS - AJ

Commanding General
U.S. Army Electronic Proving Ground
Ft. Huachuca, Arizona
Attn: Technical Library

Director of Office of Special Weapons
Developments
United States Continental Army Command
Fort Bliss, Texas
Attn: Capt. Chester I. Peterson
T S Control Officer

Headquarters
Air Research and Development Command
Andrews Air Force Base
Washington 25, D.C.
Attn: RDMMS-3

Director Nuclear Safety Research
Kirtland Air Force Base, N.M.
Attn: AFCNS

Commander
Air Force Missile Test Center
Patrick Air Force Base, Florida
Code: MTRCF

Headquarters
Ogden Air Material Area
Hill Air Force Base
Ogden, Utah
Code: OGYSS

Commander
Air Force Missile Development Center
Holloman Air Force Base
Alamogordo, New Mexico
Attn: MDBG

Commander
Air Force Special Weapons Center
Kirtland Air Force Base
Albuquerque, New Mexico
Attn: SWVSA

Director, Flight & Missile Safety Res.
Norton Air Force Base
San Bernardino, California
Attn: AFCFS-M

Commanding General
Air Fleet Marine Force, Pacific
MCAS, EL Toro
Santa Ana, California

Strategic Air Command
Offutt Air Force Base, Nebraska
Attn: DOSDM

THE FRANKLIN INSTITUTE • Laboratories for Research and Development

Q-B1856-2

DISTRIBUTION LIST (Cont.)

Commander
Headquarters Ground Electronics
Engineering
Installation Agency
Griffiss Air Force Base
Rome, New York
Code: ROZMWT

Armed Services Explosives Safety Board
Department of Defense
Room 2075, Bldg. T-7, Gravelly Point
Washington 25, D.C.

U.S. Atomic Energy Commission
Division of Military Application
Washington 25, D.C.

Aerojet-General Corporation
P.O. Box 296
Azusa, California
Attn: Myra F. Grenier, Librarian

Headquarters
Armed Services Tech. Info. Agency
Arlington Hall Station
Arlington 12, Virginia
Via: Naval Weapons Lab.
Dahlgren, Va.
Attn: WH (10)

Commander
Field Command
Defense Atomic Support Agency
Albuquerque, New Mexico
Attn: FCDR3

Aerojet-General Corporation
P.O. Box 1947
Sacramento, California
Attn: R.W. Froelich, Dept. 6620
POLARIS Program

American Machine and Foundry Co. -
Alexandria Division
1025 North Royal St.
Alexandria, Va.
Attn: Dr. L.F. Dytrt
(Contract AF-29(601)-2769) d

Atlas Powder Company
Reynolds Ordnance Section
P.O. Box 271
Tamaqua, Pennsylvania
Attn: Mr. R. McGirr

The Bendix Corporation
Scintila Division
Sidney, N.Y.
Attn: R.M. Purdy

Bermite Powder Company
22116 West Soledad Canyon Road
Saugus, California
Attn: Mr. L. Lofiego

Chance Vought Aircraft Corp.
P.O. Box 5907
Dallas, Texas
Attn: A. Latsko

The Franklin Institute
20th St. & Benjamin Frankly Parkway
Phila. 3, Penna.
Attn: Mr. E.E. Hannum, Manager
Applied Physics Laboratory (2)

Grumman Aircraft Engineering Corp.
Weapons Systems Department
Bethpage, Long Island, New York
Mr. E.J. Bonak

Hanscom Air Force Base, Mass.
Codes-AFCCDD/CCSEI-1
Attn: Capt. Long

Jansky and Bailey, Inc.
1339 Wisconsin Avenue, N.W.
Washington, D.C.
Attn: Mr. F.T. Mitchell, Jr.
(Contract N178-7604)

Librascope Division
General Precision, Inc.
670 Arques Avenue
Sunnyvale, California
Attn: Mr. R. Carroll Maninger

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

DISTRIBUTION LIST (Cont.)

Lockheed Aircraft Corporation
P.O. Box 504
Sunnyvale, California
Attn: Missile Systems Div., Dept. 62-20
Mr. I.B. Gluckman
Attn: Missiles & Space Div. Dept. 66-32
Mr. E.W. Tice
Attn: Missiles & Space Div. Dept. 81-71
Mr. R.A. Fuhrman

McCormick Selph Associates
Hollister, California
Attn: Tech. Librarian

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri
Attn: Security Officer

Patterson Moos Research
Division of Leeson Corporation
90-28 Van Wyck Expressway
Jamaica 18, New York
Attn: Mr. S. Wallack

Mr. C.M. Fisher
RCA Service Company
Systems Engrg. Facility
Government Service Dept.
838 N. Henry Street
Alexandria, Virginia
Attn: Mr. E.B. Johnston

Sandia Corporation
Albuquerque, New Mexico
Attn: Division 1262
Via: FCDASA

The Library
Thiokol Chemical Corporation
Reaction Motors Division
Denville, New Jersey

University of Denver
Denver Research Institute
Denver 10, Colorado
Attn: Mr. R.B. Feagin

U.S. Flare Div. Atlantic
Research Corporation
19701 W. Goodvale Road
Saugus, California
Attn: Mr. Norman C. Eckert,
Head R&D Group

Welex Electronics Corporation
Solar Building, Suite 201
16th and K. Streets, N.W.
Washington 5, D.C.

North Am. Aviation, Inc.
Communications Services
4300 E. 5th Ave.
Columbus 16, Ohio

Convair
Division of General Dynamics
Corporation
Pamona, California
Attn: Division Library

American Potash & Chemical Corp.
National Northern Division
P.O. Box 175
West Hanover, Mass.
Attn: Mr. J.A. Smith
Security Officer

National Aeronautics & Space
Administration
Wallops Station
Wallops Island, Virginia
Attn: Head Range Safety Section

Deputy Inspector General for
Safety
Norton Air Force Base, Calif.
Attn: AFIG-B

D.S. Bassett
Support Equipment Dept., Bldg. 6
Mail Station C1048
Hughes Aircraft Company
Culver City, California

THE FRANKLIN INSTITUTE • *Laboratories for Research and Development*

Q-B1856-2

DISTRIBUTION LIST (Concl.)

Chief
Defense Atomic Support Agency
Washington 25, D.C.
Attn: Major Melvin H. Johnsrud

W.L. Maxson Co.
475 Tenth Avenue
New York 18, N.Y.
(Contract DA-28-017-ORD-4728)

UNCLASSIFIED

UNCLASSIFIED